Effects of a modified Danish fat tax on food consumption and nutrients intake in Spain

W. Dogbe[1]; J.M. Gil[2]

1: University Polytechnic of Catalonia, ESAB - CREDA-IRTA, Spain, 2: University Polytechinc of Catalonia, ESAB-CREDA-IRTA, Spain

Corresponding author email: wisdom.dogbe@upc.edu

Abstract:

Our current dietary habits are the major cause of obesity and related diseases change. Denmark introduced fat tax in 2011 that was abolished in 2012 because of detrimental economic impacts. However, post-tax studies show that the tax was beneficial in reducing saturated fat consumption from the targeted foods. Demand- side measures have been proven to be efficient at reducing unhealthy foods. This study aims to assess the distributional effects impact of introducing a Danish-type fat tax (DFT) equivalent on food demand in Spain. Alternative tax policy scenarios have been considered taking into account policy that compensate consumers with subsidies form the taxes and otherwise. In the case where the taxed food categories only represent a subset of total food categories, a revenue-neutral approach has been designed. Expenditure as well as own- and cross-price and nutrient elasticities were calculated from an EASI food demand system. The tax reduced the consumption of the food products with saturated fat or lipid higher than 2.3%. Total lipid declined while carbohydrate intake increased. The effect is significantly reduced when revenue-neutral scenarios are considered. Distributional effect of the tax is more evident on household's heads who are obese, overweight, and younger.

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Introduction

After the UK, Spain has the highest prevalence rate of obesity in the EU (OECD, 2012). The last available National Health Survey showed that in 2011–2012 the prevalence of overweight and obesity among Spanish adults was 53.7% (ENIDE, 2012). By 2030, the projected obesity rate will reach 36% and 21% for men and women, respectively (WHO, 2013). The prevalence of obesity and overweight have mainly been attributed to unhealthy dietary composition (large amount of red meat, soda, and pastries) and a lack of physical exercise. However, literature suggest that the spread of obesity and related diseases are multifactorial (Cutler et al., 2003).

Policies in Spain have been publicly- and socially- oriented. Public policies include reducing the number of advertisements aimed at children below 18 years between 6 am and 10 pm (General Law for Audiovisual Communication), promoted by the Spanish Food Safety and Nutrition Agency or banning the sale of food and drinks with high saturated fat, trans-fat, salt or sugar additives in schools (de Lago, 2011). Social policies include action plans that are directed towards making the population physically active through the national "sports for all" policy, mandatory physical activities in all primary and secondary schools, or the inclusion of physical activities into school curriculum (Obesity - policymaker survey, 2013).

In any case, past policies have been shown not to be very effective (Kuchler, Tegene, & Harris, 2005). Moreover, eating habits are the result of a complex mixture of different factors (socio-economic and environmental factors, lifestyles, culture, traditions, etc.), which, in many cases, are very difficult to change with non-coercive measures. In the United States, some researchers and health policy advocates have started to demand more prescriptive measures to tackle bad dietary habits (Kuchler et al., 2005). Among these measures, market intervention policies are becoming very popular. Current nutritional, political and social policy instruments need complementary policies for long-term impacts. As such, the review of the effectiveness of the so-called “fat and nutrient taxes” in France, Finland, Denmark, Mexico and some parts of US, should give us some guidance.

Market interventions are traditionally justified to correct for market failures (i.e. externalities associated to increasing public health costs etc.). A recent body of literature also justifies market intervention from the notion of paternalism, that is, individuals may have potential self-control problems or time inconsistent preferences underlying the consumption of unhealthy food, thus not behaving as fully rational (Aronsson & Thunström, 2005; Cutler et al., 2003; O’Donoghue & Rabin, 1999). In addition, Cawley (2003) also justifies market intervention based on information asymmetry: individuals have a lack of knowledge about the potential consequences associated with certain diets.

Since no single policy instrument can be effective on its own, Nestle (2002) suggest five simultaneous changes in public policies intended to improve the quality of diet and to reduce obesity: 1) education reforms; 2) food labelling and advertising reforms; 3) health care and training requirements; 4) transportation and urban facilities requirements; 5) and tax policy reforms (i.e. increasing taxes for unhealthy foods and subsidies for healthy ones). The first four policies have been applied already in Spain. Despite the reluctance of policy makers in Spain to resort to tax reforms, the analysis of the potential impacts of taxes deserve special attention within empirical literature (Battle & Brownell, 1996; Kuchler et al., 2005; Marshall, 2000) In general terms, tax reforms can adopt the following two formats:

I. Measures addressed to change the relative price of foods, making healthy foods cheaper relatively to unhealthy ones. That is, reducing (increasing) the Value Added Tax on some healthy (unhealthy) products or modifying taxes for healthy/unhealthy components of food (saturated fat, cholesterol, etc.). Despite the differences in literature, taxes on nutrients have become very popular in recent years.

II. A tax on excess body weight (a tax on obese people) based on the social costs that obese people cause to society. In USA, fast food chains are introducing implicit taxes on overweight people (Greenhouse, 2003). Even though there is a consensus that a tax on excess body weight would be more effective than price interventions, it's limited by information asymmetry and use of crude means to reduce body weight.

Several countries have introduced either of these forms of taxes on food consumption as a way of internalizing negative externalities associated with the intake of unhealthy foods (Springmann et al., 2016). In October 2011, Denmark introduced a fat tax (Smed, 2012). In 2011, Hungary also passed an excise tax on foods and beverages high in caffeine, fat, and sugar, which included both soft drinks and energy drinks (Escobar et al., 2013). Similarly, Finland, in 2011, introduced a tax on sweets, ice-creams and soft drinks. Following Hungry, Denmark and Finland, France introduced the 'soda tax' in January 2012 (Berardi et al., 2016). The Mexican government in September 2013 imposed excise taxes on sugar-sweetened beverages (SSBs) and a sales tax on several highly energy dense foods (Colchero et al., 2016) to reduce the prevalence of obesity and related diseases. Berkley (California, USA) was the only state in the USA to have taxed soda and SSBs (Cornelsen & Carreido, 2015). In a meta-analysis, Escobar et al. (2013) showed that increasing the prices of these unhealthy foods led to a reduction of the prevalence of obesity and overweight. Jensen & Smed (2013) also found that the consumption of fat in Denmark dropped by 10% following the fat tax in 2011. Moreover, in both cases, they showed that fat taxes were effective in internalizing negative externalities (health expenditure associated to diseases related to obesity).

However, lately, tax policies have been increasingly criticized for several reasons: first, since the goal of these policies have been mainly revenue-oriented, they have been criticized as relatively ineffective on improving public health (WHO, 2015; Bødker et al. 2015). Second, food policy taxes face political and economic challenges (Sarlio-Lähteenkorva & Winkler, 2015). The experience in Denmark has shown that administrative costs were large for many companies generating some reluctance towards such policies. The Washington Post (2012) reported that the Danish Food Workers Union estimated the job losses at the manufacturer and retail levels at 1,300). However, it is difficult to isolate the tax effect from the global economic recession that invaded Europe after 2010.

Despite these criticisms, the analysis of the effectiveness of tax policies has been the core of a substantial number of papers and studies. These studies have relied on range of estimation methods, notably demand models, tax scenarios (compensated and/or uncompensated), and food categories. Firstly, in relation to the models, most studies have relied on the Almost Ideal Demand model (Jensen et al., 2016; Salois & Tiffin , 2011), difference-in-differences regressions Falbe et al. (2016) and consumption models based on Tobit estimation (Jensen & Smed, 2013) or fixed effects demand models (Biró, 2015). Secondly, Jensen et al.(2016), Falbe et al. (2016) , Jensen & Smed (2013) and B'iró (2015) reviewed uncompensated tax policies that have been applied whilst Salois & Tiffin , 2011 used an arbitray tax rate to simulated a compensated or revenue-neutral tax scheme. In terms of food groups, all studies attempted partial food demand models (i.e. regular soda, energy drinks, fruit drinks, sweetened coffee or tea; minced beef, regular cream, and sour cream; butter, blend, margarine and oils etc.) under the assumption of strong separability between food groups.

The above papers provide sound empirical evidence that: 1) impact of taxes on food product and nutrient consumption can be computed using food or nutrient demand elasticities; 2) taxes on food products based on their saturated fat levels can lead to decreased saturated fat intake and improve health even if the primary goal is not health improvement. Whilst these studies present plausible results, they are not without their own limitations and variations. This makes it difficult to compare the results. First, from a methodological point of view, most of these studies have relied on either fixed effect consumption models or AIDS model, ignoring the impact of unobserved household heterogeneity in elasticity estimates. The second criticism is that most papers relied only on a reduced number of food products are considered (meat, meat and dairy, SSBs…), ignoring potential substitution effect with excluded food categories. The tax scenarios are not comparable because most of the studies relied on either only uncompensated or compensated tax scenarios. Moreover, the impact of the tax was analysed on a limited number of food categories whereas the tax was imposed on all foods that were considered detrimental to health.

The objective of this paper is to analyse the potential effectiveness of the introduction of a fat tax in Spain. Among the different alternatives, we have chosen the introduction of a Danish-type fat tax instead of modifying the value added tax. Our contribution from previous literature is three-fold: 1) food expenditure and price elasticities are calculated from the estimation of an EASI demand model that is more flexible about the functional form of the Engle curves and takes into account unobserved household heterogeneity; 2) a revenue-neutral scenario is introduced for comparison purposes against the traditional uncompensated scheme oriented to increase public budget to compensate increasing health expenditure; 3) the effectiveness of the fat tax is assessed taking into account inter-relations among all foods categories. Additionally, this is the first empirical application to analyse the effect of a Danish-type fat tax in Spain.

The rest of this paper is organized as follows. The next section provides provide a description of data and empirical methodology. In the third section, results and discussions of the analysis are presented, and finally concluded with limitations and recommendations.

Data and model

Data

This study uses microdata: home scan panel data from a sample of 1146 households[1] in Catalonia (Northeast Spain) collated by Kantar Worldpanel. From the total of 1146 households, only those who had remained in the sample for at least 45 weeks were considered. Purchased quantities and expenditures for each single food product reference have been aggregated to the annual level for each household. The data set contains all day-to-day records of food purchases of Catalonian households in 2012. Each record in the Kantar data set contains detailed product information down to the Universal Product Code (UPC) level, including the store in which the household makes the purchases, product weight, price, unit of measurement, product characteristics (such as container type, brand, and flavor) and some household socio-demographic characteristics such as nationality, age, social class, presence of kids, number of pets, size of pets etc. Household´s also recorded, in a book, non-UPC items as fresh fruits or vegetables, and in-store packaged breads and meats.

[1] The sample is designed to represent the sociodemographic characteristics of households in Catalonia. Each household is assigned a weight in order to estimate total consumption for Catalonia. In this study, working with the raw data, only rural households are slightly underrepresented.

Using established Spanish Ministry of Agriculture´s nutrition-based guidelines, food products have been aggregated into 16 food categories (alcoholic drinks are not included, while non-alcoholic drinks are included in the residual category for the purpose of this paper (see Table 1 for the food categories).

To standardize the products, all quantities were converted into kilograms and prices into euros. Products with similar descriptions and characteristics were aggregated using unit values into aggregate products. Similar to Zhen, Brissette, & Ruff (2014) the lowest level of aggregation was the brand. The aggregate products were identified as belonging to subgroups and then to one of the 16 commodity groups.

To circumvent the problem of unit values encountered in cross-sectional data, we followed Diewert (1998) to construct Fisher price indices for the 16 food groups in our data using brands as the lowest level of aggregation. The Fisher price index which is the geometric mean of the Laspeyeres and Paache indices, represents the deviation of the price paid by a household relative to the average household. For instance, to construct the price index for the residual category, we followed the following procedure:

1) Determination of the price per unit for a relatively homogeneous in-quality product. In this case the unit value for the aggregate product *g* in food commodity group *j* for household *i* was calculated as: $UV_{gj}^{i} = \frac{\sum_{m=1}^{M} p_{mgj}^{i} * q_{mgj}^{i}}{\sum_{m=1}^{M} q_{mgj}^{i}}$ (1)

where p_{mgj}^{i} is household i*'s* price of the *m* brand in aggregate product *g* within the commodity group *j*, and $q_{mgj}^{i}$is household *i's* quantity purchased of the *m* brand in aggregate product *g* within the commodity group *j*.

2) Construction of the Fisher price indices using the UV_{gj}^{i} values obtained in the first stage. The Fisher price index for household *i's* commodity group *j* is calculated as:

$$P_{FJ}^{i} = \sqrt{P_{PJ}^{i}} * P_{LJ}^{i} \quad (2)$$

where P_{LJ}^{i} and P_{PJ}^{i} represent household *i*'s Laspeyres and Paasche price indices for commodity *j*, respectively.

$$P_{PJ}^{i} = \frac{UV_{gj}^{i} * q_{gj}^{i}}{UV_{gj} * q_{gj}^{i}} \quad (3)$$

and

$$P_{LJ}^{i} = \frac{UV_{gj}^{i} * q_{gj}}{UV_{gj} * q_{gj}} \quad (4)$$

Table 1 Food expenditure shares and socioeconomic characteristics of households

	Variable	Mean	Std. Dev
Expenditure Shares	Grains and grain-based products	4.48	0.03
	Vegetables and vegetable products	13.06	0.07
	Starchy roots, tubers, legumes, nuts and oilseeds	1.64	0.01
	Fruit and fruit products	20.68	0.09
	Beef, veal and lamb	2.06	0.02
	Pork	1.99	0.01
	Poultry, eggs, other fresh meat	6.74	0.04
	Processed meat products	3.66	0.02
	Fish and seafood	4.62	0.03
	Milk and dairy products	20.97	0.10
	Cheese	2.40	0.01
	Sugar and confectionary and prepared desserts	5.53	0.03
	Plant based fats	2.65	0.02
	Composite dishes	6.26	0.05
	Snacks and other foods	0.77	0.01
	Residual Category	2.47	0.02
Socio-Demographics	High Social Class	0.213	0.41
	Low Social Class	0.197	0.40
	Lower Middle Social Class	0.238	0.43
	Middle Social Class	0.352	0.48
	18-34 years	0.090	0.29
	35-49 years	0.422	0.49
	50-64 years	0.332	0.47
	60+ years	0.155	0.36
	Presence of Kids 0-5 years	0.158	0.36
	Presence of Kids 5+ years	0.198	0.40
	No Kids	0.644	0.48

Source: Author´s own computation, 2017

where UV_{gj}^{i} is the unit value for aggregate product g in commodity j for household i as defined previously, UV_{gj} is the unit value for aggregate product g in commodity j for the average household and q_{gj} is the average quantity purchased for aggregate product g in commodity j for the average household. Table 1 shows the main household characteristics of the sample used in this paper. In the upper part, data on food expenditure[2] shares of the sixteen food groups are provided. As can be observed, the average household spends 21% of the food expenditure on fruits and fruit products, and milk and milk product imitates, respectively. The next significant food category for the average household is vegetables and vegetable products, followed by poultry, eggs and other fresh meat. The food category that attracted the lowest expenditure share is snacks and other foods. Among the socio-demographic characteristics, the most relevant for the purposes of this study are the age, presence of kids and the social class.

Table 1 shows that, 21%, 20% and 59% percent of the households belong to the high, low and middle social class category, respectively. Households with kids were in the minority representing 35.6% of the sample.

Estimating food price and nutrient elasticities

Theoretically consistent food demand models have always been the basis for simulating the effects of changes in food prices resulting from the imposition of fat taxes and subsidies on the distributions of food consumption. The most commonly employed models of demand are the Linear Expenditure Demand model and the Almost Ideal Demand System (AIDS) of Deaton & Muellbauer (1980). However, Lewbel & Pendakur (2009) recently developed an Exact Affine Stone Index (EASI) demand model that circumvents the theoretical and empirical limitations of these models. As such, our food price elasticities have been calculated by estimating an approximate version of the EASI demand model (Lewbel & Pendakur, 2009), which incorporates unobserved household characteristics. The EASI demand model has several advantages over the traditional Almost Ideal Demand System (AIDS), as it derives the Implicit Marshallian demand function which combines desirable properties of both the Hicksian and Marshallian demand functions. Moreover, the error terms can be interpreted as unobserved preference heterogeneity among individuals and Engle curves can adopt any shape over real expenditures. Finally, similar to the AIDS model, we can estimate a linear approximation which generates results similar to the full model.

[2] Food expenditure used in our data refers to food-at-home expenditure. Kantar Worldpanel did not provide data on food-away-from-home neither on household income. Henceforth, we have assumed weak separability of food-at-home expenditure on total expenditure. Instead of income, the dataset provides information about the social class the household belongs. Social class is defined by relations of ownership or control or resources (i.e. physical, financial, and organizational).

The approximate EASI demand equation expresses the budget shares, $\boldsymbol{w^j}$, as a function of food prices *p*, total household food expenditure *y*, and *l* number socio-demographic characteristics *z*:

$$\boldsymbol{w^j} = \sum_{r=0}^{R} \boldsymbol{b_r \bar{y}^r} + \boldsymbol{Cz} + \boldsymbol{Dz\bar{y}} + \sum_{k=1}^{j} \boldsymbol{Ap} + \boldsymbol{Bp\bar{y}} + \boldsymbol{\varepsilon} \qquad (5)$$

where $\boldsymbol{b_r}$, is a R_{th} vector of parameters (*r*= 0,1,2,...,5) that control the shape of the Engel curve (up to a fifth-order polynomial); $\boldsymbol{\bar{y} = x - \acute{p}\bar{w}}$ is the j_{th} log of the Stone index-deflated nominal food expenditure ($\boldsymbol{x}$ is the nominal food expenditure and $\boldsymbol{\bar{w}}$ represents the vector of mean budget shares); *C* is a *LxJ* matrix of parameters corresponding to socio-demographic variables excluding the intercept; *D* is the *LxJ* matrix of coefficients from interaction between the real food expenditure ($\boldsymbol{\bar{y}}$) and the socio-demographic variables ($\boldsymbol{z} = (\boldsymbol{z_1}, \dots, \boldsymbol{z_l})$); *A* is a *JxJ* matrix of price coefficients; *B* is a *JxJ* matrix of coefficients from interactions between food expenditure and prices; and $\boldsymbol{\varepsilon}$ is the vector of error terms., which accounts for unobserved preference heterogeneity. For the model to be consistent with theory, the budget share equations $\boldsymbol{w^j}$ are required to satisfy the properties of adding-up, linear homogeneity and Slutsky symmetry.

The EASI demand system was estimated using 3-Stage least Squares to account for endogeneity. There are two sources of endogeneity. First, the presence of budget shares in the stone index makes this index to be endogenous[3]. Second, as we have seen in the previous paragraph, the real food expenditure ($\boldsymbol{\bar{y}}$) is a function of the dependent variables (shares). In our conditional food-at-home demand model, we have controlled for this form of endogeneity by we creating an instrument using a variable that is strongly correlated with household income, that is, social class. To create our instrument, we regressed social class and other exogenous variables (presence of kids and age) and their interactions with social class on total household expenditure. We generated the linear predictors and the square of the linear predictors from the model and introduced these into our demand model as instrument.

By deriving (5) with respect to log prices and expenditure, we get the Marshallian demand semi-elasticities, which were converted into price elasticities following Castellón, Boonsaeng, & Carpio (2015) and expenditure elasticities following Zhen, Brissette, & Ruff (2014)

[3] Lewbel and Pendakur (2009) and Zhen et al. 2014 have shown that this source of endogeneity in demand models is numerically unimportant.

- Hicksian price elasticities for good *j* with respect to the price of product k was calculated as:

$$\boldsymbol{h_{jk}} = \frac{(\boldsymbol{A^{jk}} + \boldsymbol{B^{jk}}\boldsymbol{y})}{\overline{\boldsymbol{w^k}}} + \overline{\boldsymbol{w^j}} - \boldsymbol{\delta} \qquad (6)$$

where δ*ij* =1 if *j* =k, and 0 otherwise

- The J x 1 vector of expenditure elasticities was calculated as:

$$\boldsymbol{e_j} = (\boldsymbol{W})^{-\mathbf{1}}[(\boldsymbol{I_j} + \boldsymbol{EP'})^{-\mathbf{1}}\boldsymbol{E}] + \mathbf{1}_{\boldsymbol{j}} \qquad (7)$$

where W is the $J \times J$ identity matrix where the ones have been replaced by the commodities' budget shares, E is a $J \times 1$ vector whose i_{th} element equals $\sum_{r=1}^{R} \boldsymbol{rb_r y^{r-1}} + \boldsymbol{Dz} + \boldsymbol{Bp}$, P is the $J \times 1$ vector of log prices, and 1_J is a $J \times 1$ vector of ones.

- The Marshallian price elasticity, $\boldsymbol{e_{jk}}$, is recovered from the Slutsky equation using:

$$\boldsymbol{\varepsilon_{jk}} = \boldsymbol{h_{jk}} - \boldsymbol{w^j} * \boldsymbol{e_i} \qquad (8)$$

After computing the matrix of price elasticities in (6) and (8) the next step is compute the matrix of nutrient elasticities. The nutrient elasticities provide information on how the intake of specific nutrients, such saturated fat or proteins, may change as a result of price changes due to the imposition of fat taxes or subsidies. We have used the approach stated by (Huang, 1996)under the assumption that changes in the price of a particular food or in total food expenditure will affect the consumption of all food items and will simultaneously change intakes in a variety of different nutrients. Three pieces of information are needed: the food expenditure elasticities, price elasticities, and the nutrient composition of each food. The matrix of nutrient elasticity (**N**) is obtained by the matrix of food aggregate nutrient shares (**S**) and the matrix of own and cross-price demand elasticities (**D**).

$$\boldsymbol{N} = \boldsymbol{S} * \boldsymbol{D} \qquad (9)$$

where **N** is the *l x n* matrix of nutrient elasticities in response to changes in food prices (*l* indicates the number of nutrients and *n* the number food products), **S** is the *l x n* matrix with entries in each row indicating the food commodity´s share of a particular nutrient, and **D** is the *n x n* matrix of demand elasticities.

Measuring the impact of fat tax on food and nutrient consumption

To measure the impact of the fat tax on nutrient demand, we needed data on kilograms of nutrient per kilogram of each food product. Although several studies in Spain have provided some figures, there is not any single study that covers all the food categories considered in this study. Instead of using alternative sources, we have used the nutrient database from the United States Department of Agriculture (USDA-ARS, 2017), which provide information on 44 nutrients and 93,600 food products. The calculated values for daily nutrient[4] intake for all food products consumed in Catalonia are shown in Table 2.

Fat tax scenarios

Among the different tax scenarios that have been used in the literature, in the paper we have simulated the imposition of a Danish-type fat tax for two main reasons: 1) scenarios based on modifying the Value Added Tax are difficult to extrapolate as indirect tax structures are different in EU countries; 2) this tax has been already imposed and could be easily applicable to any country. The Danish fat tax was implemented with the aim of revenue creation for the Danish government. The tax was applied to food products high in saturated fat; thus affecting dairy products, vegetable oils and meat (GAIN report, 2011). The tax rate was DKK 16 (2.15 Euros) per kg saturated fat and applies to domestic and imported food products with a saturated fat content exceeding 2.3%. The maximum value was settled to the equivalent of a value added tax (VAT) of 25% (Jensen & Smed, 2013).

Unlike the Danish case, in this study we have considered two alternative tax scenarios: 1) uncompensated scheme (only the tax is applied to the unhealthy food categories, as it was implemented in Denmark); and 2) compensated scheme (some subsidies are introduced for healthier products to generate a revenue-neutral scenario). To calculate the tax to be imposed in Spain, we have updated the Danish tax to 2016 values using the Danish Consumer Price Index (CPI). Then, we have used the Purchasing Power Parity (PPP) and exchange rates between Spain

[4] This was calculated as the weighted mean using the frequency of purchase as weights. The entire table comprising of the 40 nutrients are available upon request.

and Denmark to calculate the equivalent tax rate in 2016. The resulted value was 1.47 euros per kg of saturated fat.

Under the uncompensated scenario, the tax Δp_i on the i-th food category was calculated as:

$$\Delta \boldsymbol{p_i} = \boldsymbol{k_i} * \boldsymbol{\tau} \qquad (11)$$

where $\boldsymbol{k_i}$ is the average saturated fat contained in food group i , is DFT tax rate imposed on 1 kg of saturated fat per kg of food.

Under the compensated case, the price for each subsidized aggregate food was calculated:

$$\boldsymbol{P_i} = \boldsymbol{p_0} - \emptyset * \boldsymbol{p_0} \qquad (12)$$

Table 2 Tax simulation scenarios

Source: Author´s own computation, 2017

		UNCOMPENSATED (Percent Change in Prices + 4 or 10% VAT)	**COMPENSATED**
Food groups	Saturated Fat (g)/100g	DFT	DFT
Grains and grain-based products	0.82	0.00%	-4.30%
Vegetables and vegetable products	0.04	0.00%	-4.30%
Starchy roots, tubers, legumes, nuts and oilseeds	1.34	0.00%	-4.30%
Fruit, fruit products and fruit and vegetable juices	0.00	0.00%	-4.30%
Beef, veal and lamb	3.50	5.64%	5.64%
Pork	3.06	4.64%	4.64%
Poultry, eggs, other fresh meat	3.55	3.56%	3.56%
Processed and other cooked meats	9.66	15.13%	15.13%
Fish and other seafood	0.69	0.00%	-4.30%
Milk, dairy products and milk product imitates	1.15	0.00%	-4.30%
Cheese	18.64	28.04%	28.04%
Sugar and confectionary and prepared desserts	8.82	13.57%	13.57%
Plant based fats	23.11	36.38%	36.38%
Composite dishes (animal and vegetable composite dishes)	0.76	0.00%	-4.30%
Snacks and other foods	3.89	6.06%	6.06%

where $\emptyset$, is a consistently positive factor, p_0, is the original or baseline price of each aggregate food group that is untaxed. $\emptyset$ is the subsidy that makes the revenue from uncompensated case equal to zero in the compensated case. The taxes and subsidies computed for the compensated and compensated schemes are shown in Table 3. The percentage reduction in the quantities of food products and nutrients consumed after imposing the tax were calculated taking own- and cross-price elasticities into account. The change in quantity demanded for each aggregated food group was calculated as:

$$\frac{\Delta Q^{j}}{Q_{j}} = \sum_{k}^{m} \boldsymbol{\varepsilon_{jk}} * \frac{\Delta p_k}{p_k} \qquad (13)$$

where $\frac{\Delta P}{P}$ and $\frac{\Delta Q}{Q}$ represent the percentage change in prices and quantities (nutrient & consumption) of each food group after the tax, respectively (Säll & Gren, 2015). $\boldsymbol{\varepsilon_{jk}}$ is the own- and cross- price nutrient elasticities of the aggregate food group *j*.

Finally, the post-tax change in nutrient consumption, $\Delta \boldsymbol{E_i}$, taking into account own- and cross-price nutrient elasticities (5) was defined as

$$\Delta \boldsymbol{E_i} = \sum_{k=1}^{l} \boldsymbol{N} * \boldsymbol{q_i} \qquad (14)$$

where q , is the average nutrient in grams per day in each of the aggregate food groups, and $\boldsymbol{N}$ being the nutrient elasticities of ith food aggregate.

Results and Discussions

Food demand elasticities

The EASI demand model in (5) has been estimated imposing adding-up, homogeneity and symmetry. Several Wald tests have been carried out to check for model adequacy. In relation to the functional form of the Engle curve, we followed a sequential procedure. We considered first a 5-degree polynomial and test for the significance of the fifth parameter. As the p-value was 0.75, we consider a fourth-degree polynomial as test for the significance of the fourth parameter. Its p-value was 0.50. We repeated the process with a cubic functional form and here we obtained a 0.005 p-value, indicating that a cubic functional form was appropriate in our case. Finally, we tested for the joint significance of the interaction parameters between socio-demographic variables and prices and real food expenditure, respectively. Results indicated that parameters associated to interactions with prices were not jointly statistically significant (p-value 0.78), while were significant in the case of real expenditure (p-value 0.003).

Table 4 below shows the price and the expenditure elasticities of all the food aggregates at the mean level. The elasticities for the various socio-demographic groups are not discussed here; however, they are available upon request. We found all price elasticities to be negative, inelastic and significant with the exception of snack and other food category which was negative but elastic and insignificant. Among the meat categories, beef, veal and lamb category was the most inelastic. The implication is that the price of beef, veal and lamb category is less responsive to price changes compared to the other meat categories. Among the meat categories poultry, eggs, and other fresh meats were more responsive to price changes.

Fruits, fruit products and fruit and vegetable juices were more responsive to price changes than fresh vegetables and vegetable products. Snack and other foods were price elastic that implies very sensitive to price changes probably because of the obesity awareness and campaign against sugary foods which are predominantly snacks.

Our expenditure elasticity estimates show that only vegetables and vegetable products; fruit, fruit products and fruit and vegetable juices; and poultry, eggs, other fresh meat categories were expenditure elastic with the rest being expenditure inelastic. In contrast to the price elasticity estimates, these foods are more sensitive to expenditure changes than to price changes. Among the meat groups, sensitivity to expenditure is very close, however, poultry, eggs, other fresh meat category was more responsive. Comparing our expenditure elasticities to previous studies, Garc'\ia-Muros et al. (2017) found Fruits (1.02) and Vegetables (1.03) to be slightly expenditure elastic. Similarly, Molina (1994) and Laajimi, Gracia, & Albisu (1997) found fruit and vegetables to have expenditure elasticity of 1.333 and 1.034, respectively, in Spain. Contrary to our results, Garc'\ia-Muros et al. (2017) found poultry to be inelastic (0.850). However, Molina (1994) and Laajimi, Gracia, & Albisu (1997) summed all meat into one category and found meat consumption to be expenditure elastic in Spain.

All own-price elasticities estimates are statistically significant at the 5% level and negative, except for beef, veal and lamb and the residual category, which are significant at the 10% level. All food categories have absolute price elasticities less than unity, except for the residual food category. We found price elasticities for fruit and fruit products and vegetable and vegetable products to be -0.75 and -0.66, respectively. This is in line with the previous findings from Molina (1994) and

Laajimi, Gracia, & Albisu (1997) although both studies combined fruits and vegetables into one single category and found price elasticities to be -0.68 and -0.836, respectively.

Table 3 Estimated mean food price and expenditure elasticities

Food Group	Unconditional Marshallian Price Elasticities	Expenditure Elasticities
Grains and grain-based products	-0,254***	1,020***
Vegetables and vegetable products	-0,657***	1,200***
Starchy roots, tubers, legumes, nuts and oilseeds	-0,613***	0,785***
Fruit, fruit products and fruit and vegetable juices	-0,748***	1,086***
Beef, veal and lamb	-0,165**	0,983***
Pork	-0,718***	0,989***
Poultry, eggs, other fresh meat	-0,848***	1,108***
Processed and other cooked meats	-0,334***	0,985***
Fish and other seafood	-0,414***	1,050***
Milk, dairy products and milk product imitates	-0,635***	0,959***
Cheese	-0,439***	0,789***
Sugar and confectionary and prepared desserts	-0,560***	0,773***
Plant based fats	-0,311***	0,894***
Composite dishes	-0,468***	0,768***
Snacks and other foods	-0,686***	0,683***
Residual Category	-1,396	0,843**

, **,*, represent significance at 10%, 5% and 1%, respectively*
Source: Author´s own computation

All animal and dairy products were found to be price inelastic. Beef, veal and lamb had the lowest price elasticity (-0.17) contrary to the findings of Garc'\ia-Muros et al. (2017), which can be attributed to differences in the data sets used, the geographical context (as we deal only with Catalonia) and on how food categories have been defined and aggregated.

We found 150 complementarities among food categories and 115 substitutions. Most of the cross-price[5] elasticities are significant and plausible. For instance, we found that poultry, eggs and other fresh meat category is a close substitute for all animal products including fish and marine products. We also found complementarity between all animal products and fruits and fruit products. Grains and grain based products and vegetable and vegetable products are complement to all animal products, starchy roots, tubers, legumes, nuts and oil seeds. Finally, milk and other dairy products

[5] Cross-price elasticities are not presented here due to space limitations, however, they are available upon request.

were found to be complementary to cheese. Other relationships are less intuitive but this is likely to happen when estimating demand models with minimal functional form restrictions Zhen et al. (2013).

Effectiveness on the fat tax on daily consumption

As expected, under the uncompensated scheme, the tax has a negative impact on the daily consumption of all food categories despite the fact that the fat was imposed only in some food categories (see Figure 1). Under the compensated scheme, the consumption of grains and grain-based products; fruit, fruit products and fruit and vegetable juices; milk, dairy products and milk product imitates; and Composite dishes increased: However, vegetable and vegetable products and fish and other seafood declined despite being subsidized.

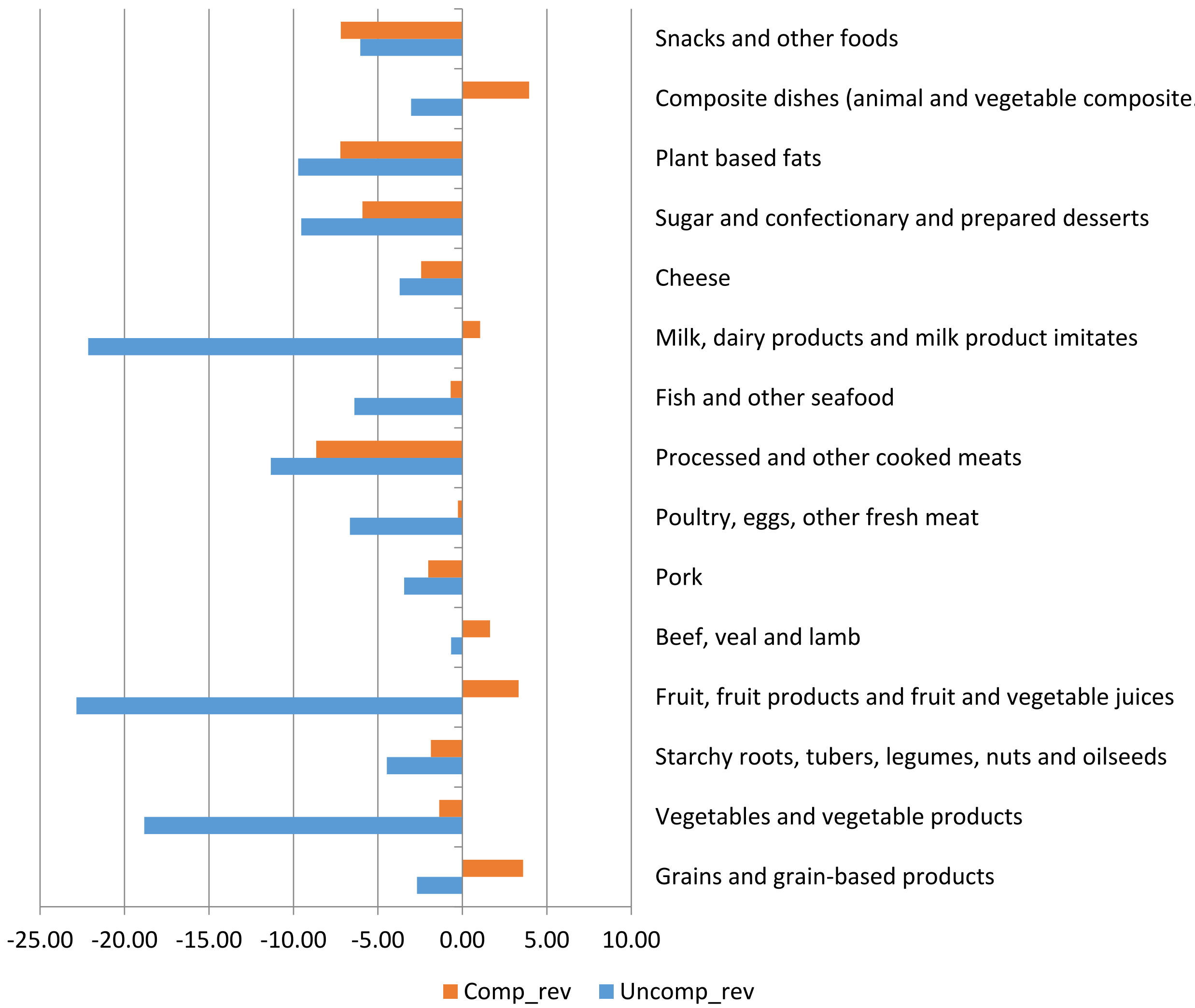

Figure 1. Post-tax reductions in consumption quantities

This indicates that subsidizing vegetables and vegetable products do not necessarily translate into increased consumption due to strong substitution effects with health damaging foods. Hence, studies that ignore substitution and complementarity among foods when simulating fiscal policies are likely to underestimate the potential impact of the tax (Mytton et al., 2007). Our results support previous studies that showed that fat tax could lead to a reduction in consumption variety of food groups especially where they are not coupled with subsidies (Mytton et al., 2007; Smed et al., 2007). For instance, Mytton et al. (2007) concluded that the beneficial effects of a fat tax is that the fat tax produces modest but meaningful changes in food consumption and a reduction in cardiovascular disease.

Impact on nutrient redistribution

In this section, we show the impact of the tax policies on nutrient intake ratios by comparing actual estimates with the recommended macronutrient intake ratios. The recommended dietary macro-nutrient intake ratios according to WHO are 15:55:35 for protein, carbohydrate and lipid, respectively (in %). The current average nutrient intake ratios were estimated to be 16:41:42 for protein, carbohydrate and lipid, respectively (Table 5). This indicates that there is excess consumption of protein and fats, while a deficit in carbohydrate intake. Hence, a fat tax that is able to redistribute the ratios towards the recommended nutrient ratios is plausible.

The imposition of the fat tax suggests the following results. There is a significant 6% increase in the carbohydrate intake increased, in the compensated case, but it decreases in the uncompensated case by 2%. In any case, the increase in the compensated case is not enough to arrive at the recommended levels.

The lipid intake decreases under both scenarios; however, the reduction is lower in the compensated case. In terms of protein intake, Table 5 shows that the impact of the tax is negative in the uncompensated case, moving Catalonian consumers towards the dietary guidelines. However, in the compensated case, the effect of the tax is negative as it increases the protein intake moving it away from the recommendation level. Results in this paper are consistent with those found by Tiffin & Arnoult (2010) who concluded that, taxing saturated fat (0.00 - 15%) and subsidizing fruit (14.78%) was insufficient to achieve the goal of nutrient redistribution.

Table 4 Comparison of macronutrient intake ratios

Nutrients	Recommended %	Actual %	Uncompensated changes (%)	Compensated changes (%)
Protein	15.0	15.8	-1.7	1.0
Lipid	30.0	41.6	-4.0	-1.1
Carbohydrate	55.0	41.5	-1.8	5.6
Saturated Fat	8.0	15.6	-3.2	-0.6
Mono saturated Fat	20.0	15.1	-4.4	-1.5
Poly saturated Fat	5.0	7.4	-5.7	-2.2

Source: Author´s own computation, 2017

Distributional impact of the fat tax

Once we have analysed the global results, in the following section we will concentrate in the distributional effect of the tax in different household segments. We have considered two socio-demographic variables included in our model: 1) the Body Mass index (BMI) of the head of the household, segmenting the sample in four groups: underweight, normal weight, overweight and obese; and 2) the age of the household head, segmenting the sample again in four groups: 18-34 years old, 35-49 years old, 50-64 years old and 65+ years old.

Let us start by considering the effect of the tax taking into account the BMI of the head of the household. Figure 2 shows the effects in the uncompensated scenario: As can be observed, the energy intake slightly decreases for all individuals except for the underweight segment, in which a slight increase is observed. The most significant decrease takes place in the obese population, arriving at -3.4%. In terms of the lipids intake, again the obese individuals exhibit the largest reduction (up to -6.3%) while overweight individuals recorded the least reduction (-1.3%). Sugar intake increased for underweight (3.9%) and normal weight (4.19%) individuals but decline for obese (-0.04%) and overweight (-0.23%) individuals. Carbohydrate intake increased for underweight and normal weight individuals but reduced for overweight and obese persons. In terms of lipid and carbohydrate intake, the tax is more effective on obese. Although, the reduction are small, in the long run, this policy, if sustained, could lead to weight reduction and better health outcomes.

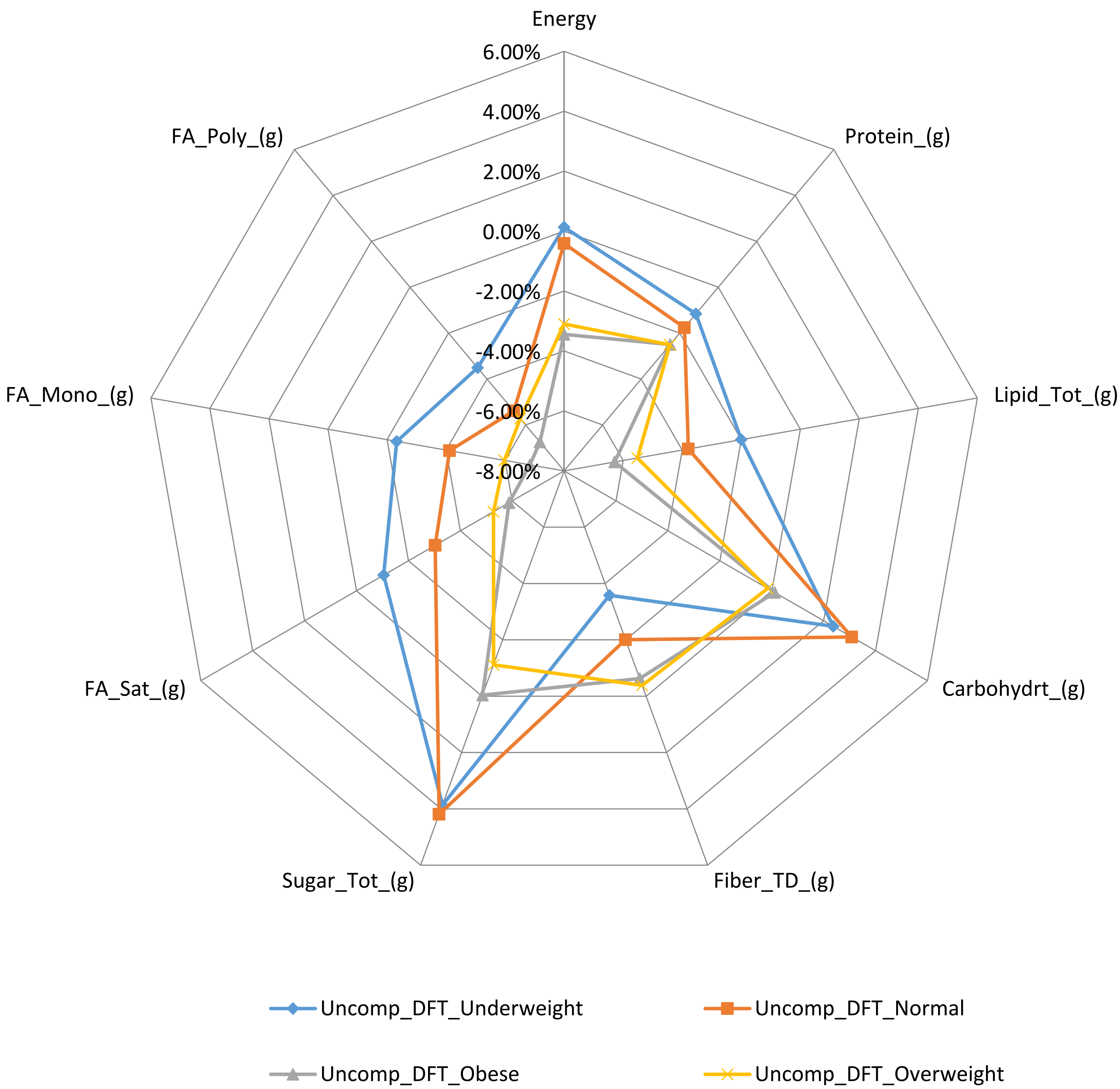

Figure 2 Effect of the tax on nutrient intake by BMI categories (uncompensated case)

The effects of the compensated tax scenario are shown in Figure 3. Results are significantly different in relation to the previous case. Reduction in energy intake is much lower for obese individuals (-0.43%). Contrary to the uncompensated case, lipid intake decreased for all weights except for underweight persons. Similar to the uncompensated case, sugar intake increased for underweight and normal weight persons. Contrary to the uncompensated case, carbohydrate increase is much higher for all weight groups. In summary, the uncompensated the tax scheme is more effective for all weight groups although reductions and increases are marginal.

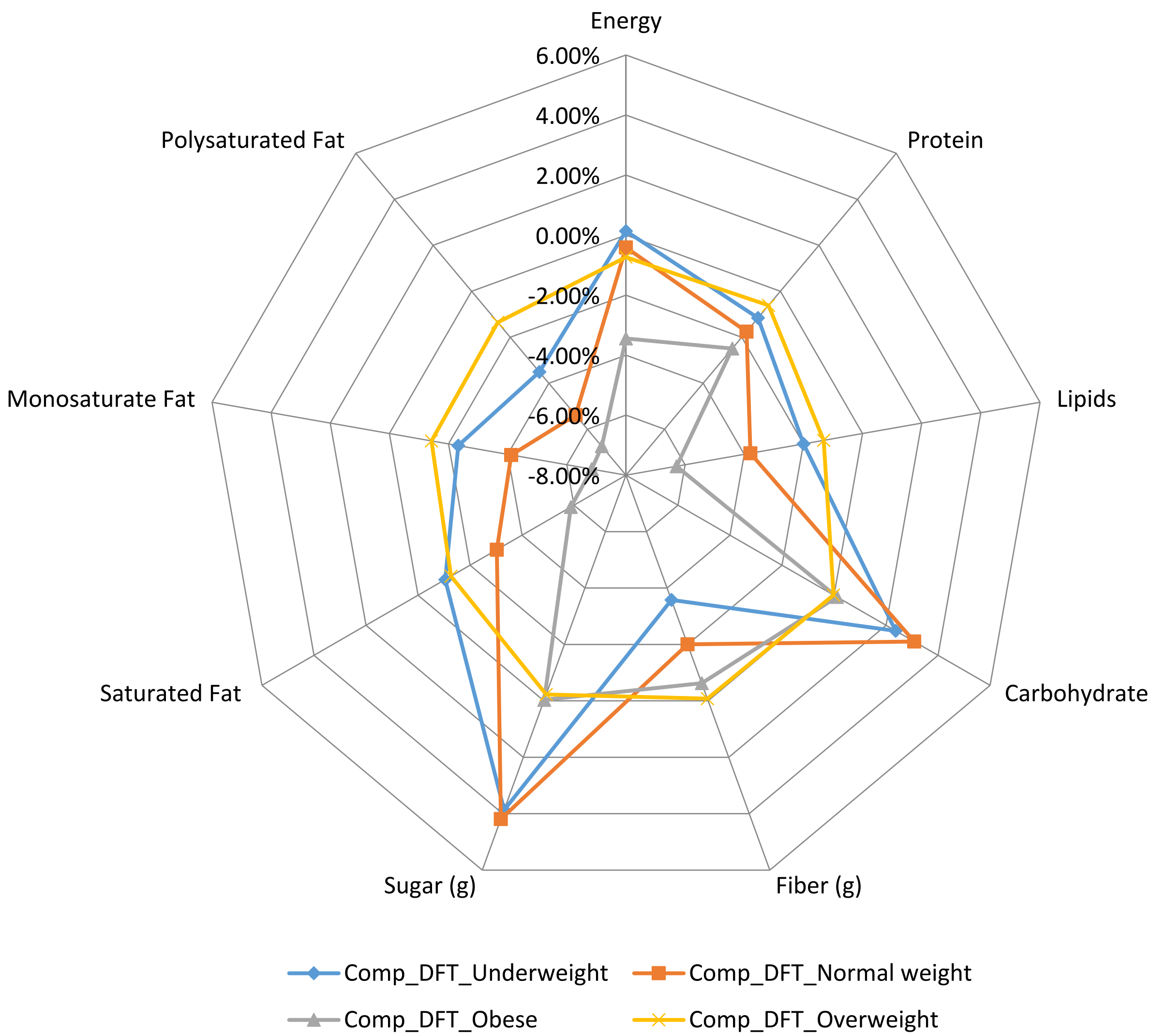

Figure 3 Effect of the tax on nutrient intake of BMI categories (compensated case)

Also for the different age groups, the result in the uncompensated case is different from the compensated case. Figure 4 shows that energy intake declined across all ages, the highest reduction estimated for people between 35 and 49 years old. The reduction in lipid consumption is highest for people between 35 and 49 years old but lowest for the oldest population. With the exception of intermediate ages (35 to 49 years old), carbohydrate intake increased for all other age groups. This is plausible because majority of people with these age groups are obese or predispose to overweight and obesity. With the exception of age groups 18-34 and 35-49 years, sugar intake decreased. This shows that the reduction in energy is replaced from other sources. In the compensated case, the tax is effective on ages 35-49 who are also predispose to being obese.

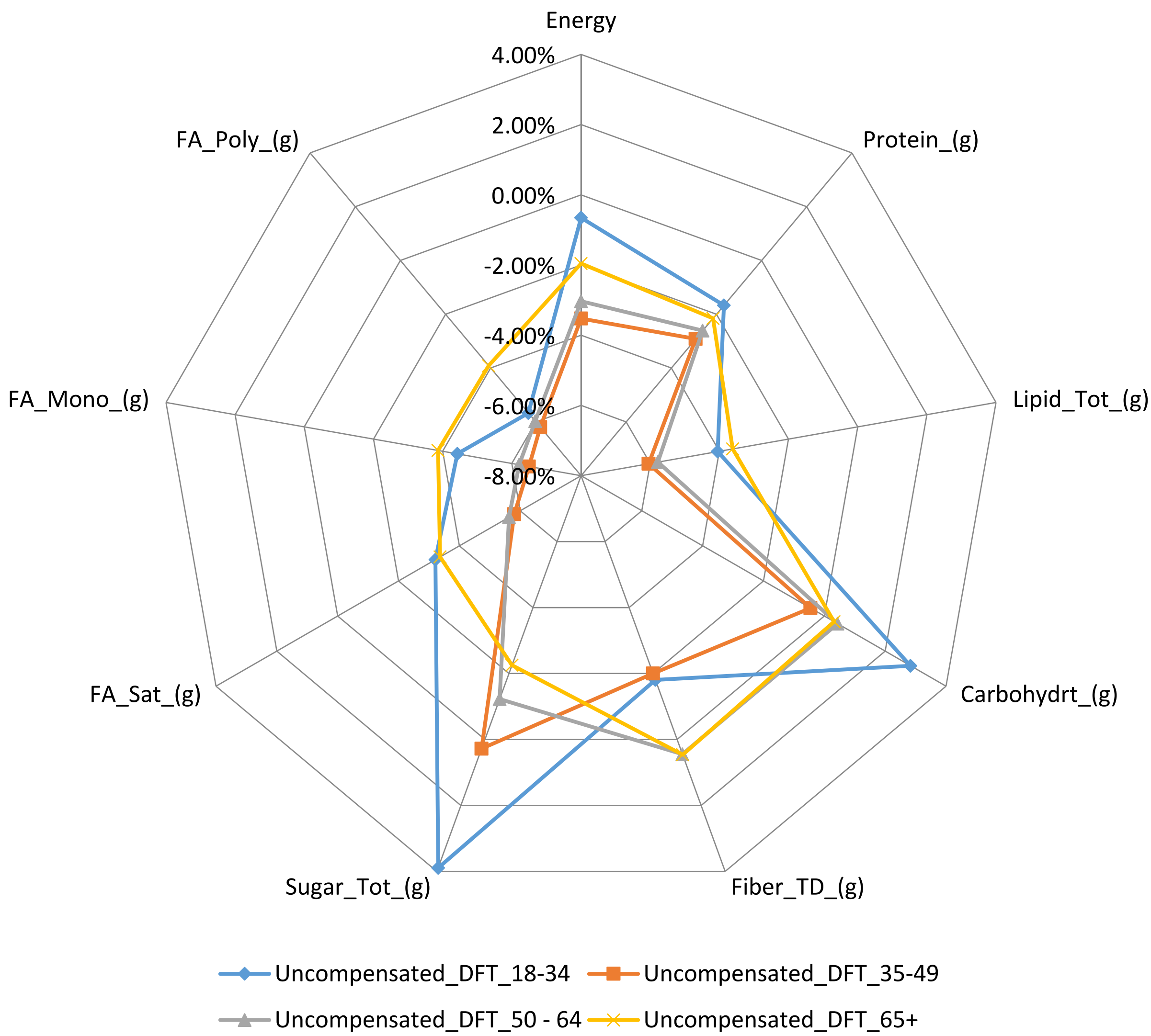

Figure 4 Impacts of the fat tax on nutrient intake of age groups (uncompensated case)

Similar to the uncompensated case, Figure 5 shows that energy intake declined for age groups between 35-49 years (-0.36%) and 50-64 years (-0.20%), however, increased for ages 18-35 years (2.2%) and 65+ years (0.63%). Lipid intake declined across all age groups but lower than previously; highest for ages 50-64 years (-2.8%) and the lowest 65+years (-0.86%). Also, carbohydrate consumption increased across all ages. The highest increase estimated for 18-34 (5.64%) years in carbohydrate and lowest for 65+ (2.78 %) years. Sugar intake increased across all ages except for individuals that are 65+ years. The tax was effective in increasing the consumption of carbohydrate but less effective on lipid reduction. Also, energy intake declined for age groups predisposed to obesity and increased for those less predisposed. In terms of lipid reduction, the tax is effective on both ages 50-64 and 35-49 years.

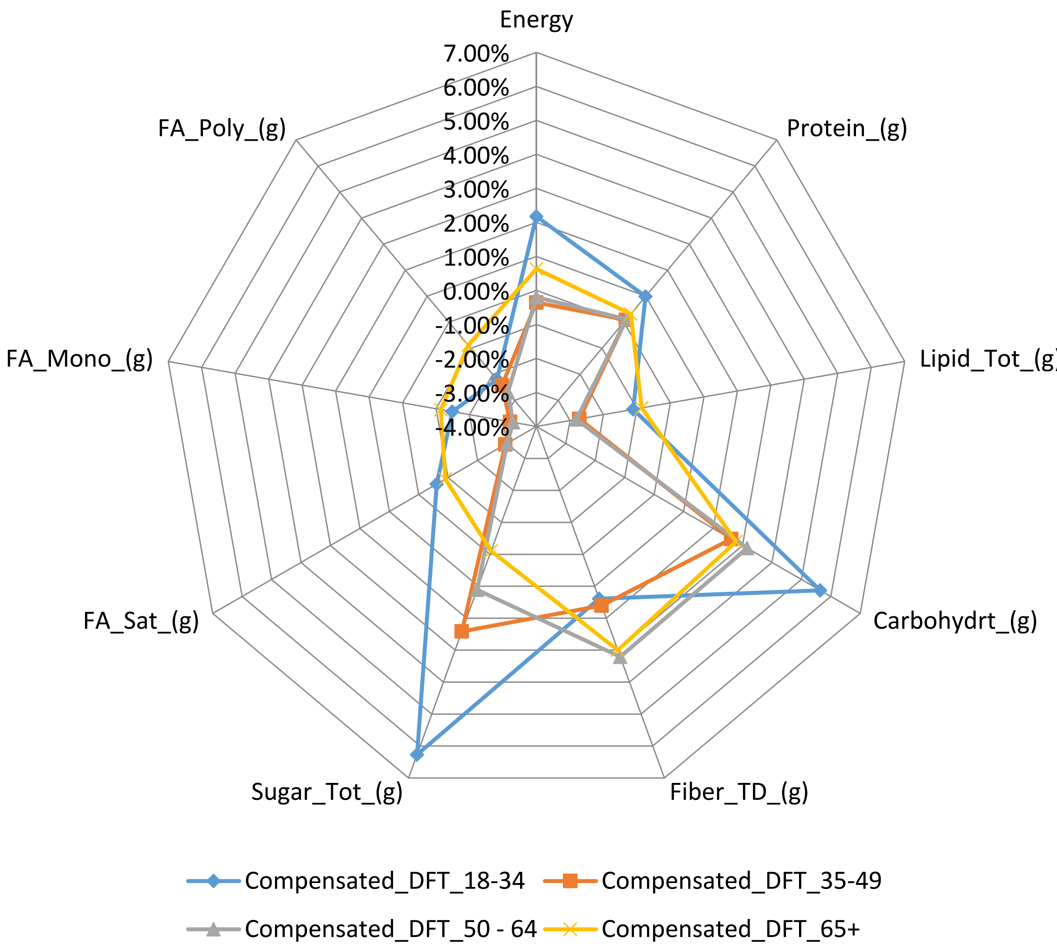

Figure 5 Impacts of the fat tax on nutrient intake of age groups (compensated case)

As have been observed, the imposition of a fat tax has different outcomes depending if policy makers have in mind a revenue-generating goal or not. We found that the tax is more effective where subsidies are not implemented (uncompensated) due to the strong complementarities that exist between non-taxed and taxed foods. Comparing the different tax schemes, we found that the tax in both the compensated and uncompensated cases lead to a reduction in lipid and saturated fat intake, however, an uncompensated tax scheme is more effective. In terms of BMI, the tax is more effective on obese individuals and more effective in the uncompensated case. In terms of ages, the uncompensated results are somewhat correlated with the BMI results, since those who are between ages 35-49 are more predispose to obese, the tax is more effective on them. In the compensated case, the tax is more effective on those between ages 50-64 years.

Even if percentage changes are not very high, results from this study should not be underestimated taking into account recent studies in the clinical journal literature. In fact, Siggaard, Raben, & Astrup (1996) and Swinburg et al. (1997) showed that even a small reduction in fat intake contributed to reduce body weight. For instance, Westerterp et al. (1996) found that reducing dietary fat by 2% resulted in weight maintenance. Yu-Poth et al. (1999) supported this view by showing that 1% reduction in energy from total fat led to 0.28 kg decrease in weight. Similarly, Astrup, Grunwald, Melanson, Saris, & Hill (2000) from a meta-analysis showed that 1% reduction in dietary fat could lead to weight loss of about 0.37 Kg (95% CI, 0.15 to 0.6 kg). These clinical trial results indicate that even though the reduction in fat or saturated fat intake is small, it could lead to a beneficial health outcome if sustained especially in the uncompensated case.

Conclusion

The evidence provided in this paper suggests that the impact of the DFT on Spanish consumers could be beneficial if prolonged. First, since we imposed a DFT, we show that considering substitutions and complementarity among all foods, the tax will have less effect on fat reduction in Spain. Comparing both the compensated and uncompensated cases, we found that the tax is more effective if uncompensated tax scheme is pursued. Similarly, the tax is more effective on obese persons in the uncompensated case than the compensated case as the reduction in lipid is much less. There is a strong correlation between the results for obese person and ages 35-49 years in the uncompensated. As a result, the tax is more effective on ages 35-49 than all other ages. The implication is that pursing an uncompensated tax scheme could have more beneficial impact and raise revenues for government. However, considering that clinical trials studies support that small changes in dietary fat could have beneficial health outcomes, economically, it is less regressive for consumers if a compensated tax scheme is pursued. As such, since there isn´t significant difference between fat reduction under the compensated and uncompensated schemes, it is plausible if government to pursues a compensated tax policy scheme since this could improve the consumptions of foods that are less damaging to health.

This study is without its limitations. Firstly, since our data set does not record household income and FAFH we had to estimate condition food at home demand elasticities. Secondly, we could not find a reliable dataset in Spain containing all the foods in our data so we have to rely on external sources like the USDA data for the estimations of the different nutrients and consumption quantities in our data.

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